

Evidence of climatic change during Holocene in the nearshore regions of Konkan (central west Coast of India)

ANUP R. GUJAR and MEDIMI V.S. GUPTHA

Anup R. Gujar and Medimi V.S. Gupta - National Institute of Oceanography, Dona Paula, Goa-403 004, India.

Abstract

In order to understand the paleoenvironmental setting of the nearshore area of the central west Coast of India, three vibro-cores from the Kalbadevi Bay, from a depth range of 6-12 m were analysed for sedimentological, mineralogical and micropaleontological aspects.

The results have shown that during Early Holocene (Younger Dryas), arid climates prevailed which may be correlatable with global aridity. This has been inferred from feldspar/quartz ratio, occurrence of gypsum crystals, iron stained quartz grains, variation in the stability index and significantly poor diversity and scarcity of benthic foraminifera. In contrast, during the mid Holocene humid phase, the number of benthic foraminifera was very high. It is also remarked that *Ammonia beccarii* and *Florilus scapha* were abundant during humid and arid phases respectively.

KEY WORDS: Holocene, paleoenvironment, arid/humid phases, foraminifera, feldspar/quartz ratio, stability index.

Introduction

The Kalbadevi Bay is one of the arcuate and semi protected bays situated along the Konkan Coast on the west Coast of India having two streams one each at N and S debouching into the bay with a total drainage area of about 150 km². Bathymetry and seabed surveys carried out by Siddiquie *et al.* (1979, 1982) have revealed that the sands are distributed upto a depth of 10-12 m along the coast and are very prominent at the stream mouths. Besides, the central part of the bay is marked with an E-W trending depression which is believed to be a paleochannel. The streams which originate in the foot hills of the Sahyadris are the main source of sediment supply.

The hinterland geology is largely comprised of Deccan Trap basalts (Upper Cretaceous to Lower Eocene), at places overlain by laterites of Pleistocene age. Furthermore, the coastal land forms such as sand dunes, occupy a broad area between the backshore and the salt marsh.

Much work has been carried out from the different bays along the Konkan coast, but it is largely focused on the exploration of placer deposits, bathymetry, magnetics and shallow seismic studies (Siddiquie *et al.*, 1982; Gujar *et al.*, 1989; Ramana *et al.*, 1990). No attempts have been yet made to study and understand the paleoenvironment of this region, which is the object of the present investigation.

Material and methods

In order to carry out the paleoenvironmental studies in the Kalbadevi Bay, three vibro cores were selected out of several collected on board R.V. SAMUDRA SHAUDIKAMA in collaboration with the Geological Survey of India, from water depths ranging from 6 to 12 m (Fig. 1a). The cores were later sub-sampled at every one meter

interval for the purpose of evaluation of the ilmenite placers. The sub samples were used in the present study. Sedimentological and mineralogical analyses were carried out following Folk (1961) and Hutchinson (1974). Feldspar/quartz ratios were measured from X-ray diffractograms generated by using carbonate free sample on PHILIPS PH 1840 diffractometer with nickel filtered Cu K α radiation between 25-30° 2 θ for quartz and feldspar. For micropaleontological analysis, the coarse fraction > 149 μ m was utilised.

Results and discussion

The lithologs of all the three vibro-cores (Fig. 1c) reveal that alternate units comprising sand silt and clay with varying admixtures of shells. Core 1964, retrieved from a water depth of 6 m is constituted by sand in the top 1 m interval, followed further down by a pebbly-shelly layer extending up to 3 m, and by plastic clays with pebbles of laterite and basalt. Similarly, cores 1971 and 1976, though showing a sandy layer on the top 1 m, vary further down core with alternate shelly pebbly beds and clay layers. At the base of the cores, a zone of oxidised reddish clay zone comprising assorted pebbles of laterite and basalt was observed which is almost parallel to the sea bed topography, and to the acoustic basement (Fig. 1b). The surface sediments are largely negatively skewed with high kurtosis values (1.28-27.58, ave. 9.76) suggesting winnowing action and prevalence of relic deposits. The sediment characters indicate a beach/river/barrier island environment of deposition. Besides, a dominance of wave induced currents over tidal currents and moderate to high energy and high mobility conditions have been observed in the modern setting (Rajamanickam and Gujar, 1984). The abundance of clay is noticed only beyond 12 m isobath and its absence below may be attributed to active littoral drift associated with wave action and longshore currents. The detrital mineral components include opaques (ilmenite and magnetite) which are dominantly subangular to subrounded in nature. The other heavy minerals in order of abundance are ortho- and clinopyroxenes, rutile, zircon, tourmaline, garnet,

staurolite, etc. There is no systematic trend in the concentration of heavy minerals with increasing depth. The significant compositional variation in heavy minerals may reflect the effect of varying degree of hydraulic fractionation by density (opaque to non-opaque ratio 0.3-10.76). The differences resulted from selective chemical decomposition of heavy minerals, suggesting differential weathering conditions (stability index 0.12-0.88) (Flores and Shideler, 1978). The other detrital components include quartz and feldspar. The quartz grains, as also the opaques, are predominantly subangular to subrounded and largely comprised of iron stained grains (40-50%) in 1-2 and 2-3 m intervals in core 1976. Such staining is due to the co-occurrence of hematite grains in the sediments during the period of elevated temperatures (Walker, 1967).

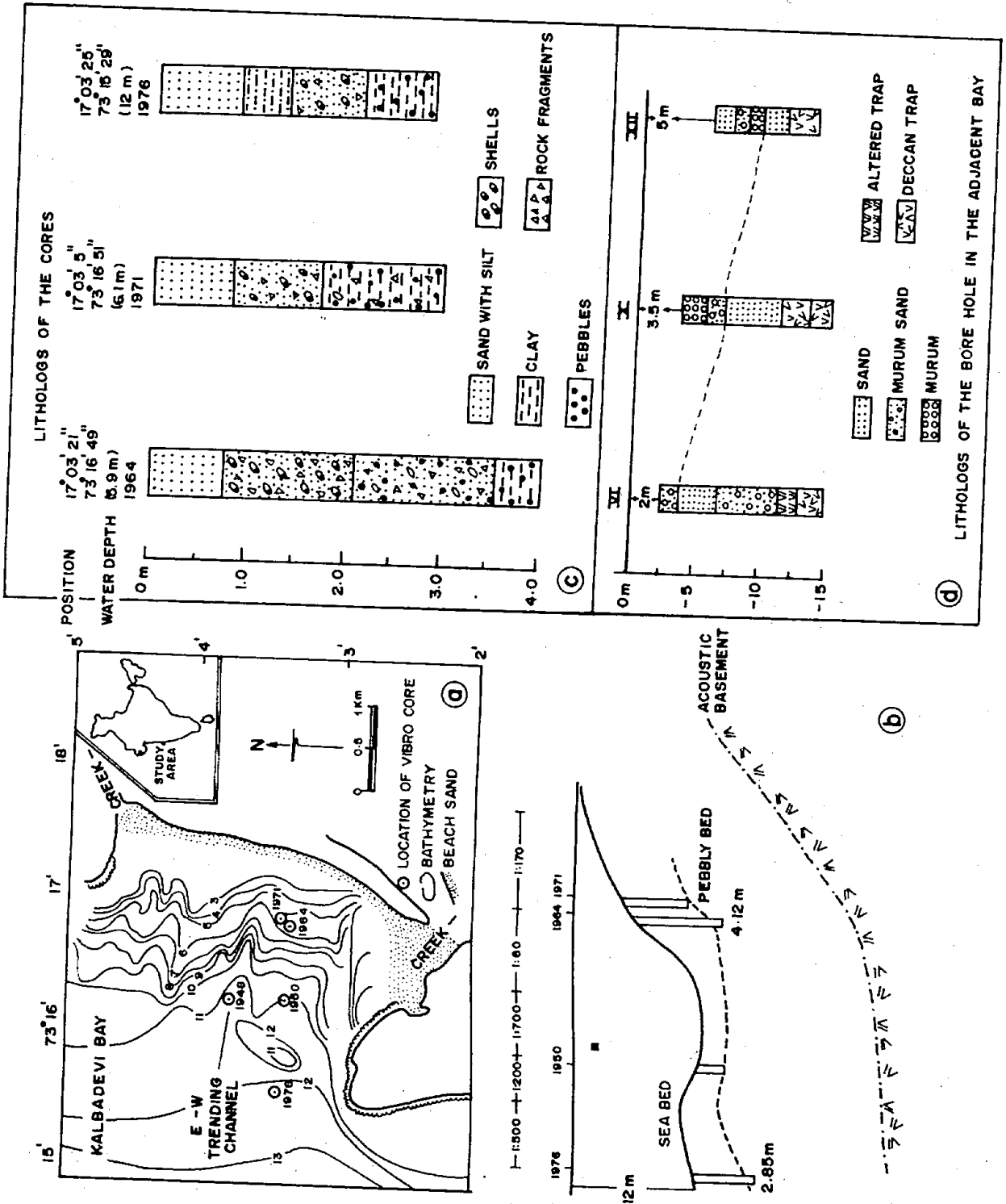
The down core distributional patterns of calcium carbonate varies from site to site. Core 1964, at 6 m water depth, displays sediments enriched in calcium carbonate from top to 2 m down core (18-22%), followed by decreasing trend further down (13-8%). Core 1971 exhibits a similar trend in calcium carbonate content from top to bottom (20-8%). At 12 m depth in core 1976, sediments are very poor in calcium carbonate (11-8%), which also shows a decreasing downward trend (Tab. 1).

At station 1948, which is near station 1976 (Fig. 1a), transparent to milky anhedral crystals of gypsum (selenite) have been reported by Sukumaran (1990). They are devoid of any feature suggesting transportation, such as rounding or abrasion.

The X-ray diffractogram (Fig. 2a) shows quartz and feldspar peaks in 26.6-26.7 and 27.7-28.0 2 θ , respectively. The type of feldspar identified is predominantly potash feldspar, according to Wright (1968). The feldspar to quartz ratio ranges from 0.06 to 0.20 (ave. 0.09) in nearshore cores at 6 m water depth, whereas it is 0.29 to 0.98 (ave. 0.61) at 12 m water depth (Tab. 1).

Siddiquie *et al.* (1979, 1982) and Gujar *et al.* (1989) have reported the occurrence of placer sands extending upto 10-12 m water depth within the bay, beyond which clay overlaps the sand. The clay/sand contact zone extends parallel to the present day beach. Ramana *et al.* (1990), from their shallow seismic investigation, have designated

Fig. 1 - Showing location (a) of vibro cores and bathymetry, (b) profile of acoustic basement, pebbly zone and sea bed across the core locations 1964 and 1976, (c) lithologies of cores 1964, 1971 and 1976 and (d) bore logs from adjacent Mirya Bay with well marked pebbly zone.



Station nos.	Depth (m)	Sediment type	CaCO ₃ %	Opaque/non opaque	Feldspar/Quartz	Stability index *
1964						
0-1 m	5.9	sand with shells	18.10	8.11	0.12	0.25
1-2 m		sand and shells	21.96	10.76	0.20	0.86
2-3 m		sand shell and pebbles	12.98	2.99	0.07	0.45
3-4 m		oxidised red clay with pebbles of laterite & basalt	7.79	2.87	0.02	0.45
1971						
0-1 m	6.1	sand with shells	20.00	5.56	0.05	0.60
1-2 m		sand, shells and pebbles	17.23	4.65	0.11	0.52
2-3 m		oxydised red clay with pebbles of laterite & basalt	08.21	0.32	0.06	0.32
1976						
0-1 m	12.0	sand with shells	11.31	1.60	0.29	0.88
1-2 m		sand, silty clay with shell	08.49	3.50	0.56	0.25
2-3 m		fragments sand upon 2.10 m oxidised red clay with pebbles of laterite & basalt	08.57	2.44	0.98	0.12

* stability index (chemical decomposition), ZTR/pH, Zircon + Tourmaline + Rutile/Pyroxene + Hornblende

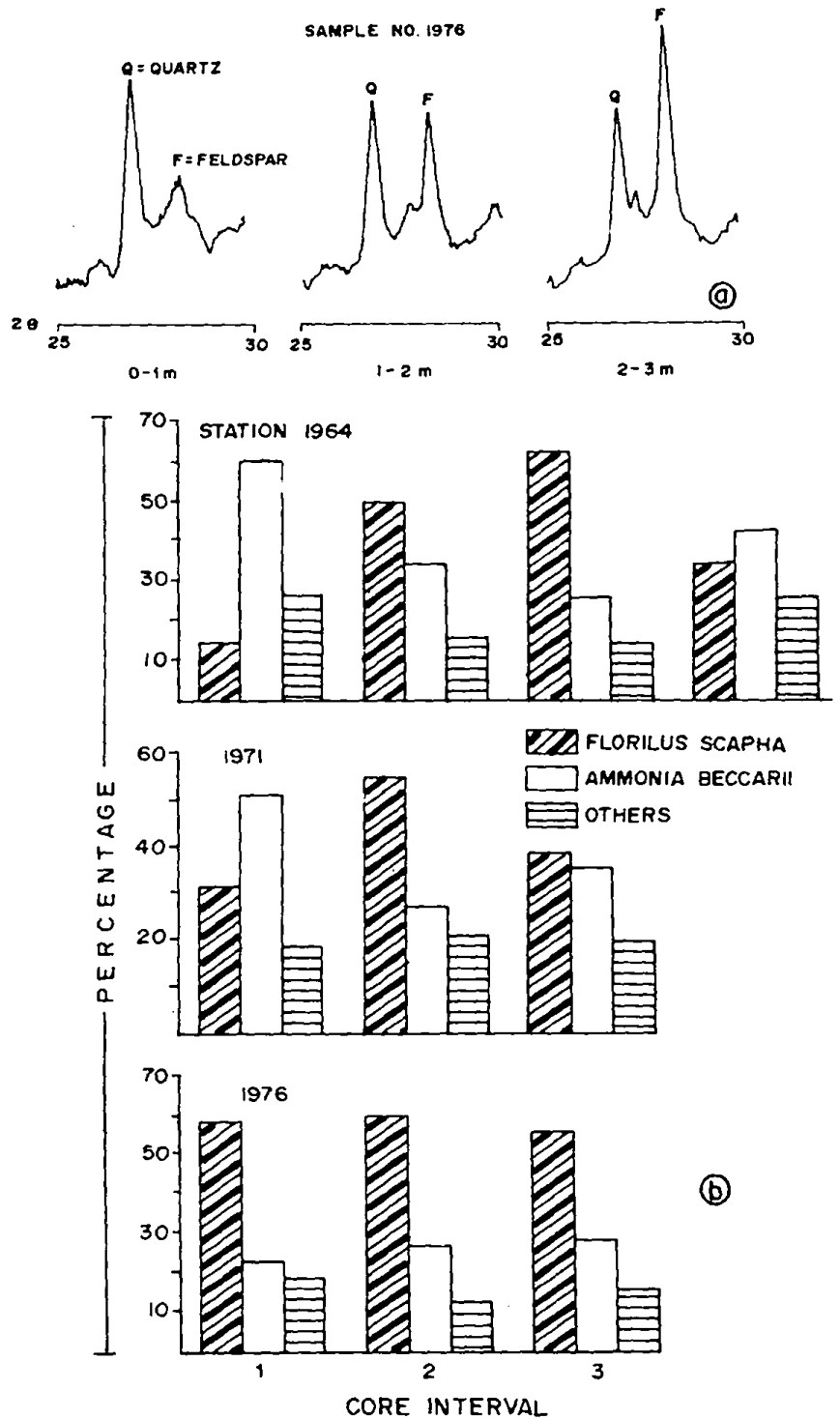
Tab. 1 - Sediment type, calcium carbonate percentage, feldspar/quartz, opaque/non opaque ratios and stability index.

this clay/sand contact zone as a paleobeach.

Kennet (1982) and Mehr (1987) have established the nature of post-Quaternary sea level fluctuations and have indicated the presence of a strand line at about 5-10 m below present sea level at 5000 years B.P. Further findings by Kale and Rajaguru (1985) and Ghate (1986), particularly from Konkan Coast, confirmed that the present sea level was attained around 5000-6000 years B.P. In view of the above, it appears that the core 1976 at 12 m water depth, which is close to the paleobeach, must have been deposited around 7500 years B.P., assuming the slow rise of sea level (about 1.4 mm/year) reported by Emery (1969) from 6000 to present.

The pebbles of laterite and basalt, encountered at 4 m level, are genetically related to coastal laterites and basalts formed before the transgression (Gujar and Srinivas, 1991). Similar pebbly beds have been also reported in the bore holes at varying intervals (1.5 m and 4 m) at 2 m and 5 m water depths respectively in the adjacent Mirya Bay (Fig. 1d). The occurrence of pebbles, along with the oxidised reddish clay zone, is indicative of prevalence of an arid climate during their formation, due to physical weathering. It is explained by the fact that weathered pebbles were subject to transportation by sheet floods caused by a strong wet spell (Schwarzbach, 1963). Relat-

Fig. 2 - (a), X-ray diffractogram of core 1976 and (b) down core variation in the percentage of *Ammonia beccarii* and *Florilus scapha*.



ively higher values of feldspar to quartz ratio in 2-3 m interval in 1976 core (Tab. 1) also indicates the prevalence of arid to semiarid conditions which tend to prevent the feldspar from weathering. However, in the absence of absolute ages, it is difficult to have

a time integrated study. Nevertheless, the top ~85 cm of sediment, represented by sand and silt layers that are uniform in all cores, should have been deposited during the active summer monsoon of Late Holocene. Below these sands, the admixture of

sand with shells and pebbles indicates high energy and high mobility conditions during strong monsoon. Such high energy conditions are also substantiated by the presence of largely of miliolid foraminifera and a high amplitude seismic facies in the sand dominated area (Ramana *et al.*, 1990). The inferred aridity in 4 m interval may be correlatable with the reported aridity during 9,000-12,000 years B.P. by Hashimi and Nair (1986) from the western continental margin of India.

Magnetic susceptibility data of core 1976 (Anon, 1990) has shown average magnetisation contrasts for different lithounits (876 and 1335×10^{-6} CGS units for sandy zone in 1-2 and 0-1 m intervals and 151×10^{-6} CGS units for clayey zone in 2-3 m interval). The variations in the susceptibility values are correlatable with the relative abundance of magnetic minerals implying a changing climate.

The distributional patterns of benthic foraminifera has yielded nineteen species of foraminifera, among which *Ammonia beccarii* and *Florilus scapha* are by far the most abundant. It was observed that the faunal diversity and abundance is high in 0-1 m, 1-2 m intervals in cores 1964 and 1971 and in 0-1 m interval in core 1976. On the contrary, they are very poor in 2-3 m and 3-4 m intervals in core 1964, in the 2-3 m interval in core 1971, in 1-2 m and 2-3 m intervals in core 1976. This suggests that when the conditions were optimum for organic production, foraminiferal abundance was high apparently during the humid phase, with nutrients supplied by land through rivers. In contrast, significantly low frequency of benthic foraminifera must have been resulted during arid conditions of the Early Holocene period, where the supply of organic matter and land derived plant nutrients were at its minimum or nil. It has also been observed that the calcium carbonate percentage and foraminiferal abundance are directly propor-

tional to each other. Besides, *A. beccarii* is predominant during the humid period except for the interval at 3-4 m in core 1964, while *F. scapha* is more abundant during the arid conditions. Such an abundance of *F. scapha* is also reported in the areas characterised by low runoff and abundant organic matter by Setty *et al.*, 1979 (Fig. 2b).

The remaining species which are sparsely distributed include: *Calcarina calcar*, *Elphidium crispum*, *E. parkeri*, *Amphistegina lessonii*, *Nonion boueanum*, *Nonion* sp., *Pararotalia* sp., *Quinqueloculina elongata*, *Q. lamareckiana*, *Q. laevigata*, *Q. seminulum*, *Spiroloculina* cf. *depressa*, *Triloculina* sp., *Textularia agglutinans* and *Virgulina squamosa*.

Conclusions

Arid conditions during the Early Holocene period (Younger Dryas) are inferred by the occurrence of iron stained quartz grains, gypsum crystals, feldspar to quartz ratio, significant variation in the stability index and the poor benthic foraminiferal diversity and abundance.

Owing to the large sampling intervals and restricted area of investigation, these conclusions have some limitations. Nevertheless, they may be correlatable with the global Holocene climatic fluctuations and, hence, are important for reconstructing the paleoenvironment.

Acknowledgement

The authors thank the Director and Head, Geological Oceanography Division of National Institute of Oceanography for their keen interest and constant support during the course of this investigation. Thank are also due to Deputy Director General of Geological Survey of India (Marine Wing, Mangalore) and Officers for their help during and after the cruise on board SAMUDRA SHAUDIKAMA-84.

REFERENCES

- ANON, 1990. Ilmenite sand resources of Kalbadevi Bay, off Ratnagiri. Geological Survey of India (Marine Wing) unpublished Report of Cruise SS-84, 1-45.
- EMERY K.O., 1969. The continental shelf. *Scientific America*, 221, 106-122.
- FLORES R.M. AND SHIDELAR G.L., 1978. Factors controlling heavy mineral variation on the south Texas outer continental shelf, Gulf of Mexico. *Journal Sedimentary Petrology*, 48/1, 269-280.
- FOLK R.L., 1961. *Petrology of sedimentary rocks*. Hamphill, Austin, Texas. 154 pp.
- GHATE S.N., 1986. «Karat» an intertidal formation of Konkan, its petrology and problem of dating. Proc. National Workshop on Carbonates, Physical Research Laboratory, Ahmedabad, 41-42.
- GUJAR A.R., RAMANA M.V. AND RAJAMANICKAM G.V., 1989. Exploration of nearshore placers of Konkan Coast, West Coast of India. Proc. 21st Offshore Technology Conference, Houston, Texas, 569-577.
- GUJAR A.R. AND SRINIVAS K., 1991. Contribution from coastal laterites to the nearshore placers of central west coast of India. *Giornale di Geologia*, 53/2, 65-70.
- HASHIMI N.H. AND NAIR R.R., 1986. Climatic aridity over India 11,000 years ago: evidence from feldspar distribution in shelf sediments. *Paleogeography, Paleoclimatology, Paleoecology*, 53, 309-319.
- HUTCHINSON C.S., 1974. *Laboratory Hand Book of Petrographic Technique*. John Wiley, New York. 385 pp.
- KALE V.S. AND RAJAGURU S.N., 1985. Neogene and Quaternary transgression and regression history of the west coast of India. An Overview. *Bulletin Deccan College Research Institute*, 44, 153-165.
- KENNET J.P., 1982. Sea level history and seismic stratigraphy. In: J.P. Kennet (Ed.), *Marine Geology*. Prentice-Hall, N.Y., 263-285.
- MERH S.S., 1987. Quaternary sea level changes in present status visa - vis records along coast of India. *Indian Earth Sciences*, 14/3-4, 235-251.
- RAJAMANICKAM G.V. AND GUJAR A.R., 1984. Sediment depositional environment in some bays in the central west coast of India. *Indian Journal Marine Sciences*, 13, 53-59.
- RAMANA M.V., GUJAR A.R. AND RAJAMANICKAM G.V., 1990. Shallow seismic studies on the inner continental shelf of selected bays, central west coast of India. *Marine Geology*, 91, 333-343.
- SCHWARZBACH M., 1963. *Climates of the past: an introduction to paleoclimatology*. D. van Nostrand Co.Ltd., London, 315 pp.
- SETTY M.G.A.P., NIGAM R. AND AMBRE N.V., 1979. Geographic pattern of foraminiferal dominance in nearshore regions of central west coast of India. *Mahasagar*, 12/3, 196-199.
- SIDDIQUE H.N., RAJAMANICKAM G.V. AND ALMEIDA F., 1979. Offshore ilmenite placers of Ratnagiri, Konkan Coast, Maharashtra. *Marine Mining*, 3, 91-118.
- SIDDIQUE H.N., RAJAMANICKAM G.V., GUJAR A.R. AND RAMANA M.V., 1982. Geological and geophysical exploration for offshore ilmenite placers of the Konkan Coast, Maharashtra, India. Proc. 14th Offshore Technology Conference, Houston, Texas, 749-755.
- SUKUMARAN P.V., 1990. Gypsum from sub bottom sediments of Kalbadevi Bay off Ratnagiri, India. *Current Science*, 59/9, 465-466.
- WALKER T.R., 1967. Formation of Red Beds in modern and ancient desert. *Geological Society of America Bulletin*, 78, 353-368.
- WRIGHT T.L., 1968. X-ray and optical studies of alkali feldspars: determining the composition and structural state from measurement of 2D values for three reflections. *American Minerals*, 53, 88-104.